

(11) **EP 0 670 350 B1**(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the grant of the patent:
05.07.2000 Bulletin 2000/27

(51) Int Cl.7: **C08L 23/12, C08L 23/16**(21) Application number: **95102938.8**(22) Date of filing: **02.03.1995**

(54) **Translucent thermoplastic elastomers**
Lichtdurchlässige thermoplastische Elastomere
Elastomère thermoplastique translucide

(84) Designated Contracting States:
DE ES FR GB IT NL

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(30) Priority: **04.03.1994 US 206984**

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(43) Date of publication of application:
06.09.1995 Bulletin 1995/36

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(56) References cited:
EP-A- 0 499 216 EP-A- 0 618 259
US-A- 4 087 485

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Printed by Jouve, 75001 PARIS (FR)

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Description

BACKGROUND OF THE INVENTION

5 Field of the Invention

[0001] This invention relates to thermoplastic elastomers which are optically translucent. A thermoplastic elastomer is generally defined as a polymer or blend of polymers that can be processed and recycled in the same way as a conventional thermoplastic material, yet has properties and performance similar to that of vulcanized rubber at service temperatures. Blends or alloys of plastic and elastomeric rubber have become increasingly important in the production of high performance thermoplastic elastomers, particularly for the replacement of thermoset rubber in various applications.

15 Description of the Related Art

[0002] Polymer blends which have a combination of both thermoplastic and elastic properties are generally obtained by combining a thermoplastic polyolefin with an elastomeric composition in a way such that the elastomer is intimately and uniformly dispersed as a discrete particulate phase within a continuous phase of the thermoplastic. Early work with vulcanized compositions is found in U.S.-A-3,037,954 which discloses static vulcanization as well as the technique of dynamic vulcanization wherein a vulcanizable elastomer is dispersed into a resinous thermoplastic polymer and the elastomer is cured while continuously mixing and shearing the polymer blend. The resulting composition is a micro-gel dispersion of cured elastomer, such as butyl rubber, chlorinated butyl rubber, polybutadiene or polyisobutene in an uncured matrix of thermoplastic polymer such as polypropylene.

[0003] In U.S.-A- Re. 32,028 (reissue of US-A-3,806,558) polymer blends comprising an olefin thermoplastic resin and an olefin copolymer rubber are described, wherein the rubber is dynamically vulcanized to a state of partial cure. The resulting compositions are reprocessible. U.S.-A-4,130,534 and 4,130,535 further disclose thermoplastic elastomer compositions comprising butyl rubber and polyolefin resin, and olefin rubber and polyolefin resin, respectively. The compositions are prepared by dynamic vulcanization and the rubber component is cured to the extent that it is essentially insoluble in conventional solvents. These products are usually opaque even if the individual components have high clarity or the compositions are unfilled. Such opaqueness is attributed to the presence of a two phase system whose domains are larger than the wavelength of light, as well as the color inherent in the compositions.

[0004] Flexible thermoset elastomers of good optical clarity have been prepared from EPDM rubber blended with very fine fumed silica and a silane coupling agent (U.S.-A-4,603,158). More recently polysiloxanes with substituent groups such as methyl-octyl have been blended with styrene-ethylene-butylene styrene (SEBS) block copolymer to yield thermoplastic elastomers with good optical properties (U.S.-A-4,613,640). Also, polypropylene impact blends containing ethylene-propylene copolymers and low density polyethylene and having good optical properties have been described in U.S.-A-4,087,485 and 4,113,806. Unlike thermoplastic elastomers, such impact polymers have poor resistance to compression set.

[0005] EP-A-0 618 259 belonging to the state of the art according to Article 54(3)/(4) EPC discloses in Examples 1-3 and 5 a partially vulcanized blend comprising syndiotactic PP and EPDMs "EP57P" and "EP07P" (trade name of Japan Synthetic Rubber), containing 28 wt.% and 27 wt.% propylene respectively. The mixture is dynamically cross-linked at a temperature of 190°C in the presence of peroxides.

[0006] US-A-4,087,485 relates to compositions having improved optical and mechanical properties comprising 70 to 95% by weight isotactic PP and 2 to 22% elastomeric ethylene-propylene copolymer (EPR) having a combined ethylene content of at least 50% which is at least partially dynamically cured in the presence of peroxides at temperatures of 187.8°C (370°F).

[0007] EP-A-0 499 216 relates to transparent moulded articles comprising 30% to 99% syndiotactic polypropylene and an uncured ethylene-propylene copolymer.

50 SUMMARY OF THE INVENTION

[0008] In detail the present invention relates to an optically translucent composition comprising

- 55 a) thermoplastic syndiotactic polypropylene homopolymer, and
b) elastomeric ethylene- α -olefin polymer having an ethylene content of at least 74 wt.%,

wherein said elastomeric polymer is fully cured.

[0009] The present invention is based on the discovery that a thermoplastic elastomer composition having the prop-

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erty of optical translucence is provided by incorporating syndiotactic polypropylene homopolymer into olefinic thermoplastic elastomers, in combination with the olefin rubber component. The rubber component of the composition is usually present as micrometer-size particles in the thermoplastic matrix, and it is fully cured. Unexpectedly, the inclusion of syndiotactic polypropylene homopolymer in the composition provides a thermoplastic elastomer which has a significantly lowered Gardner haze value, while maintaining the desirable properties of low compression set and thermal stability. The compositions have utility as molded mechanical rubber goods such as face masks and seals, as well as extruded articles such as flexible tubing and fluid delivery bags for medical and other applications.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

POLYPROPYLENE

[0010] The polypropylene used in the compositions of the invention is a crystalline material which is syndiotactic in structure. The stereochemistry of syndiotactic polypropylene is generally described as one in which the polymer principally contains units of exactly alternating configuration, as opposed to the repeating units with identical configuration in isotactic polypropylene or the random configuration of atactic polypropylene. Syndiotactic polypropylene homopolymer has a density in the range of 0.89-0.91 g/cm³ and a melting point in the range of 135 - 140° C. It may be prepared by several known processes, including the use of ionic catalysts such as the reaction product of metallocene and an activator compound as described in EP-A-0 548274. The syndiotactic polypropylene may contain minor amounts of isotactic or random polypropylene.

[0011] The amount of polypropylene found to provide useful translucent compositions is generally from 10 to 90 weight percent, based on the weight of the rubber and polypropylene. Preferably, the polypropylene content of the composition will range from 25 to 90 percent by weight, with a most preferred range of 60 to 90 percent by weight.

OLEFINIC RUBBER

[0012] Suitable olefin copolymer rubbers comprise non-polar, essentially non-crystalline, rubbery copolymers of two or α -olefins, preferably copolymerized with at least one polyene, usually a diene. Saturated olefin copolymer rubber, for example ethylene-propylene copolymer rubber (EPM) can be used. However, unsaturated olefin rubber such as EPDM rubber is more suitable. EPDM is a terpolymer of ethylene, propylene and a non-conjugated diene. Satisfactory non-conjugated dienes include 5-ethylidene-2-norbornene (ENB); 1,4-hexadiene; 5-methylene-2-norbornene (MNB); 1,6-octadiene; 5-methyl-1,4-hexadiene; 3,7-5-methyl-1,4-hexadiene; 1,3-cyclopentadiene; 1,4-cyclohexadiene; dicyclopentadiene (DCPD); and the like. Blends of any of the above olefinic rubbers can be employed, rather than a single olefinic rubber.

[0013] In preparing the compositions of the invention, the amount of olefinic rubber generally ranges from 90 to 10 weight percent, based on the weight of the rubber and polypropylene. Preferably, the olefinic rubber content will be in the range of from 74 to 10 weight percent, with a most preferred range of 40 to 10 weight percent.

[0014] It is also preferred that the ethylene (C₂) content of the olefinic rubber be 45 weight percent or higher. When the C₂ content of the rubber component is lower, the desired translucent properties of the compositions are greatly reduced. With C₂ content of at least 74 weight percent, there appears to be a synergism between the syndiotactic polypropylene and the olefinic rubber which results in a significant improvement in translucence of the thermoplastic elastomer product.

CURING AGENT

[0015] Those ordinarily skilled in the art will appreciate the appropriate quantities, types of cure systems and vulcanization conditions required to carry out the vulcanization of the rubber. The rubber can be vulcanized using varying amounts of curative, varying temperatures and varying time of cure in order to obtain the optimum crosslinking desired. Any known cure system for the rubber can be used, so long as it is suitable under the vulcanization conditions with the specific olefinic rubber or combination of rubbers being used and with the polyolefin. These curatives include sulfur, sulfur donors, metal oxides, resin systems, peroxide-based systems and the like, both with and without accelerators and co-agents. Peroxide curatives are preferred for the preparation of the translucent compositions of the invention, since they do not introduce color. Such cure systems are well known in the art and literature of vulcanization of elastomers.

PROCESSING

[0016] The olefin rubber component of the thermoplastic elastomer is generally present as micron or submicron size

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particles within a continuous polyolefin matrix. Alternatively, depending on mixing conditions and compositions, cocontinuous phase morphologies or a mixture of discrete and cocontinuous phase morphologies are also possible. The rubber is completely or fully crosslinked. The complete crosslinking can be achieved by adding an appropriate rubber curative to the blend of polyolefin and rubber and vulcanizing the rubber to the desired degree under conventional vulcanizing conditions. However, it is preferred that the rubber be crosslinked by the process of dynamic vulcanization. As used in the specification and claims, the term "dynamic vulcanization" means a vulcanization or curing process for a rubber contained in a thermoplastic elastomer composition, wherein the rubber is vulcanized under conditions of high shear at a temperature above the melting point of the polyolefin component. The rubber is thus simultaneously crosslinked and dispersed as fine particles within the polyolefin matrix, although as noted above other morphologies may also exist. Dynamic vulcanization is effected by mixing the thermoplastic elastomer components at elevated temperature in conventional mixing equipment such as roll mills, Banbury mixers, Brabender mixers, continuous mixers, mixing extruders and the like. The unique characteristic of dynamically cured compositions is that, notwithstanding the fact that the rubber component is fully cured, the compositions can be processed and reprocessed by conventional plastic processing techniques such as extrusion, injection molding and compression molding. Scrap or flashing can be salvaged and reprocessed.

[0017] The terms "fully vulcanized" and "completely vulcanized" as used in the specification and claims means that the rubber component to be vulcanized has been cured to a state in which the elastomeric properties of the crosslinked rubber are similar to those of the rubber in its conventional vulcanized state, apart from the thermoplastic elastomer composition. The degree of cure can be described in terms of gel content or, conversely, extractable components. Alternatively the degree of cure may be expressed in terms of crosslink density. All of these descriptions are well known in the art, for example in U.S.-A-5,100,947 and 5,157,081.

[0018] The following general procedure was used in the preparation of thermoplastic elastomers of the invention, as set forth in the examples. The rubber plus peroxide curative and a coagent were mixed in a Brabender mixer of 80 cm³ capacity at 100 rpm. The temperature in the mixer was maintained below about 130°C in order to disperse the curative without prematurely vulcanizing the rubber. The mix was then combined with the polypropylene and masticated under nitrogen at a temperature in the range of 160-190°C to dynamically vulcanize the rubber in the blend. When the cure was as complete as desired an antioxidant was added and mixing continued for up to about 15 minutes.

[0019] Nucleating agents for polypropylene, such as Milled 3905, may also be added in small amounts (0.1 to 1.0 phr) but mixing must then be carried out at 230°C.

[0020] Compression molded plaques of about 1.6 mm thickness were prepared at about 200°C from the dynamically vulcanized alloy (DVA), followed by cooling in the mold to minimize distortion. These test plaques were used for the measurement of physical and optical properties. Haze of the compositions was measured following the procedure of ASTM D 1003-61, with a Gardner brand Model XL-211 hazemeter. In this measurement a completely opaque material has a reading of 100%, and lower values indicate better optical clarity. No attempt was made to prepare plaques having "smooth" surfaces, and therefore the measured haze values are higher than if the plaques had an optically smooth texture.

[0021] The present invention will be better understood by reference to the following examples which serve to illustrate but not limit the invention.

Example 1

[0022] Dynamic vulcanizates were prepared following the general procedure described above, with syndiotactic polypropylene, isotactic polypropylene, random tacticity polypropylene and impact modified polypropylene. The elastomer component of the composition was selected from EPDM rubbers having ethylene (C₂) content in the range of 48-77%. The ratio of components was 76 weight percent EPDM rubber and 24 weight percent polypropylene. The compositions also included 0.51 phr (parts per hundred rubber) of α - α' -bis (t-butyl peroxy)dilsoisopropylbenzene curative, 1.65 phr of tri-allyl cyanurate coagent and 1.5 phr of bis(2,4-di-t-butylphenyl) pentaerythritol diphosphate antioxidant. Plaques were prepared from the finished compositions as described above, and haze values were determined. Results are set forth in Table I.

TABLE I

	% Haze		
	EPDM "A" (48% C ₂)	EPDM "F" (74% C ₂)	EPDM "G" (77% C ₂)
Impact polypropylene	—	100%	—
Isotactic polypropylene	100	100	100
Random polypropylene	100	71	78

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TABLE I (continued)

	% Haze		
	EPDM "A" (48% C ₂)	EPDM "F" (74% C ₂)	EPDM "G" (77% C ₂)
Syndiotactic polypropylene "1"	86	39	36
Syndiotactic polypropylene "2"	—	36	—
Syndiotactic polypropylene "3"	—	27	—
Note to Table I: only Examples "F" and "G" containing syndiotactic polypropylene "1", "2" and "3" are according to the invention. The other Examples are Comparative Examples.			

[0023] As demonstrated by these results, thermoplastic elastomers prepared using syndiotactic polypropylene homopolymer show a striking improvement in optical translucence, as compared with compositions containing isotactic, random or impact forms of polypropylene.

Example 2

[0024] Dynamic vulcanizates were prepared using the general method described above, with syndiotactic polypropylene "1" homopolymer and EPDM rubbers having C₂ contents in the range of 48-77 percent. In all cases the ratio of EPDM to polypropylene was 75/25, and the curatives and antioxidant were as set forth in Example 1. The compositions were prepared using total mixing times of seven minutes and fifteen minutes respectively. Plaques were prepared and haze values determined as described above. The results are set forth in Table II.

TABLE II

EPDM	Wt. % C ₂	Haze Values (%)	
		7 min. mixing	15 min. mixing
"A"	48	90	86
"B"	68	70	53
"C"	70	65	60
"D"	71	58	51
"E"	72	69	57
"F"	74	48	29
"G"	77	46	36
Note to Table II: Examples "A", "B", "C", "D" and "E" are Comparative Examples			

[0025] It can be seen from these results that the ethylene content of the rubber component has a synergistic effect on the optical characteristics of the thermoplastic elastomers. Higher C₂ content provides a product of increased clarity, while a C₂ content below 48 weight percent provides little if any of the translucent properties desired in the compositions of the invention. A longer mixing period after vulcanization of the blend also improves the optical properties in most instances, probably due to a reduction in particle size of the cured elastomer thus reducing the tendency to scatter light.

Example 3

[0026] A series of dynamic vulcanizates was prepared over a range of EPDM/polypropylene ratios, using the method described above. The curatives and antioxidant were as in Example 1, and mixing time was 12-15 minutes. Plaques were prepared and haze values determined. The results are shown in Table III.

TABLE III

	EPDM/PP (76/24)	EPDM/PP (50/50)	EPDM/PP (29/71)
EPDM "F", phr	100	100	100
Polypropylene "1", phr	32	100	250

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TABLE III (continued)

	EPDM/PP (76/24)	EPDM/PP (50/50)	EPDM/PP (29/71)
Gardner haze, %	40	54	66

[0027] The translucent compositions of the invention can be prepared over a broad range of rubber/polypropylene ratios.

Example 4

[0028] Compositions of the invention were prepared including a mineral oil additive to determine the effect of oil on optical clarity. Thermoplastic elastomers were prepared as described above, using a rubber/polypropylene ratio of 75/25 and a total mixing time of about 25 minutes. Plaques were prepared and both optical and physical properties were determined. Results are set forth in Table IV.

TABLE IV

	I	II	III	IV
EPDM "F", phr	100	100	—	—
EPDM "G", phr	—	—	100	100
Polypropylene "1", phr	32	32	32	32
Mineral oil ¹ , phr	0	48	0	48
Curative ² , phr	0.51	0.51	0.51	0.51
Coagent ² , phr	1.65	1.65	1.65	1.65
Antioxidant ² , phr	1.5	1.5	1.5	1.5
Hardness (Shore A)	88	65	85	58
Stress at 100% strain ³ (MPa)	4.7	7.1	5.6	7.0
Tensile strength ³ (MPa)	10.3	9.6	7.8	9.8
Elongation at break ³ (%)	374	402	187	391
Compression set ⁴ (%) (22 hours/100°C)	39	27	33	—
Haze (%)	40	38	33	40

¹ fully saturated paraffinic oil [HT Brightstock, from Petrocanada]

² same as in Example 1

³ ASTM D 412

⁴ ASTM D 395B

[0029] As can be seen from these results, the inclusion of mineral oil had no significant effect on the optical properties of the DVAs.

[0030] The components used in the foregoing examples are described in Table V.

TABLE V

Polypropylene "1"	Syndiotactic homopolymer [Grade G49M, Hoechst AG]
Polypropylene "2"	Syndiotactic homopolymer [Grade G53, Hoechst AG]
Polypropylene "3"	Syndiotactic homopolymer [Grade G20/28, Hoechst AG]
Random polypropylene	Random tacticity copolymer [Escorene PD9272, Exxon]
Isotactic polypropylene	Isotactic homopolymer [Raxene 11s07a, Lyondell]
Impact polypropylene	Impact modified copolymer [Escorene 7031, Exxon]
EPDM "A"	Ethylene-propylene-diene terpolymer [Vistalon 4808, Exxon]
EPDM "B"	Ethylene-propylene-diene terpolymer [Vistalon 707, Exxon]
EPDM "C"	Ethylene-propylene-diene terpolymer [Vistalon 7000, Exxon]
EPDM "D"	Ethylene-propylene-diene terpolymer [Epsyn 5508, Copolymer]
EPDM "E"	Ethylene-propylene-diene terpolymer [Dutral 033/E, Montedison]
EPDM "F"	Ethylene-propylene-diene terpolymer [Vistalon 8731, Exxon]
EPDM "G"	Ethylene-propylene-diene terpolymer [Nordei 2722, Dupont]

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Claims

1. An optically translucent composition comprising
 - a) thermoplastic syndiotactic polypropylene homopolymer, and
 - b) elastomeric ethylene- α -olefin polymer having an ethylene content of at least 74 wt.%,
 wherein said elastomeric polymer is fully cured.
2. The composition of claim 1 wherein the elastomeric polymer is an ethylene-propylene copolymer.
3. The composition of claim 1 wherein the elastomeric polymer is an ethylene-propylene-nonconjugated diene terpolymer.
4. The composition of claim 1 wherein the elastomeric polymer has been cured with a peroxide curing agent.
5. The composition of claim 1 comprising from 10 to 90 parts of polypropylene and from 90 to 10 parts elastomeric polymer per 100 parts of polypropylene and elastomeric polymer.
6. The composition of claim 1 wherein the elastomeric polymer is cured by dynamic vulcanization.
7. The composition of claim 1 in the form of a molded or extruded optically translucent article.
8. The composition of claim 1 obtainable by the steps of
 - a) mixing elastomeric ethylene- α -olefin polymer having an ethylene content of at least 74 wt.% and a curative until the curative is evenly dispersed in the mixture,
 - b) blending the mixture from step (a) with syndiotactic polypropylene, and
 - c) masticating the blend from step (b) under shear at a temperature in the range of 160 °C to 180 °C until the elastomeric polymer is fully cured.
9. An optically translucent composition comprising
 - a) from 25 to 90 wt.% of thermoplastic syndiotactic polypropylene homopolymer, and
 - b) from 10 to 75 wt.% elastomeric EPDM terpolymer rubber having an ethylene content of at least 74 wt.%,
 wherein said rubber is fully cured by dynamic vulcanization in the presence of a peroxide curing agent.
10. Use of the compositions of any of claims 1 to 9 as molded mechanical rubber goods or extruded articles.

Patentansprüche

1. Optisch durchscheinende Zusammensetzung, umfassend:
 - a) thermoplastisches syndiotaktisches Polypropylen-Homopolymer; und
 - b) elastomeres Ethylen- α -Olefin-Polymer mit einem Ethylengehalt von wenigstens 74 Gew.-%;
 wobei das elastomere Polymer voll ausgehärtet ist.
2. Zusammensetzung gemäß Anspruch 1, wobei das elastomere Polymer ein Ethylen-Propylen-Copolymer ist.
3. Zusammensetzung gemäß Anspruch 1, wobei das elastomere Polymer ein Ethylen-Propylen-nichtkonjugiertes-Dien-Terpolymer ist.
4. Zusammensetzung gemäß Anspruch 1, wobei das elastomere Polymer mit einem Peroxid-Härtungsmittel gehärtet ist.

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5. Zusammensetzung gemäß Anspruch 1, die 10 bis 90 Teile Polypropylen und 90 bis 10 Teile elastomeres Polymer pro 100 Teile Polypropylen und elastomeres Polymer umfaßt.
- 5 6. Zusammensetzung gemäß Anspruch 1, wobei das elastomere Polymer durch dynamische Polymerisation gehärtet ist.
7. Zusammensetzung gemäß Anspruch 1 in Form eines formgepreßten oder extrudierten, optisch durchscheinenden Artikels.
- 10 8. Zusammensetzung gemäß Anspruch 1, erhältlich durch die folgenden Schritte:
 - a) Mischen von elastomerem Ethylen- α -Olefin-Polymer mit einem Ethylengehalt von wenigstens 74 Gew.-% mit einem Vulkanisationsmittel, bis das Vulkanisationsmittel gleichmäßig in dem Gemisch dispergiert ist;
 - 15 b) Blenden des Gemischs aus Schritt (a) mit syndiotaktischem Polypropylen; und
 - c) Maschieren des Blends aus Schritt (b) unter Scherung bei einer Temperatur im Bereich von 160°C bis 190°C, bis das elastomere Polymer voll ausgehärtet ist.
- 20 9. Optisch durchscheinende Zusammensetzung, umfassend:
 - a) 25 bis 90 Gew.-% thermoplastisches syndiotaktisches Polypropylen-Homopolymer; und
 - 25 b) 10 bis 75 Gew.-% elastomeres EPDM-Terpolymer-Kautschuk mit einem Ethylengehalt von wenigstens 74 Gew.-%;

wobei der Kautschuk durch dynamische Vulkanisation in Gegenwart eines Peroxid-Härtungsmittels voll ausgehärtet ist.
- 30 10. Verwendung der Zusammensetzungen gemäß einem der Ansprüche 1 bis 9 als formgepreßte mechanische Kautschukwaren oder extrudierte Artikel.

Revendications

- 35 1. Composition optiquement translucide comprenant
 - a) un homopolymère de polypropylène syndiotactique thermoplastique, et
 - 40 b) un polymère d'éthylène- α -oléfine élastomérique ayant une teneur en éthylène d'au moins 74 % en poids,

dans laquelle ledit polymère élastomérique est complètement vulcanisé.
- 45 2. Composition selon la revendication 1, dans laquelle le polymère élastomérique est un copolymère d'éthylène-propylène.
3. Composition selon la revendication 1, dans laquelle le polymère élastomérique est un terpolymère d'éthylène-propylène-diène non conjugué.
- 50 4. Composition selon la revendication 1, dans laquelle le polymère élastomérique a été vulcanisé avec un agent de vulcanisation de type peroxyde.
5. Composition selon la revendication 1, comprenant de 10 à 90 parties de polypropylène et de 90 à 10 parties de polymère élastomérique pour 100 parties de polypropylène et de polymère élastomérique.
- 55 6. Composition selon la revendication 1, dans laquelle le polymère élastomérique est vulcanisé par vulcanisation dynamique.
7. Composition selon la revendication 1, sous la forme d'un article optiquement translucide extrudé ou moulé.

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8. Composition selon la revendication 1 susceptible d'être obtenue par les étapes consistant à

- 5 a) mélanger un polymère d'éthylène- α -oléfine élastomérique ayant une teneur en éthylène d'au moins 74 % en poids et un agent de vulcanisation jusqu'à ce que l'agent de vulcanisation soit uniformément dispersé dans le mélange,
b) mélanger le mélange de l'étape (a) avec un polypropylène syndiotactique, et
c) pétrir le mélange de l'étape (b) sous cisaillement à une température dans la gamme de 160°C à 190°C jusqu'à ce que le polymère élastomérique soit complètement vulcanisé.

10 9. Composition optiquement translucide comprenant

- 15 a) de 25 à 90 % en poids d'un homopolymère de polypropylène syndiotactique thermoplastique, et
b) de 10 à 75 % en poids de caoutchouc de terpolymère de EPDM élastomérique ayant une teneur en éthylène d'au moins 74 % en poids,

20 dans laquelle ledit caoutchouc est complètement vulcanisé par vulcanisation dynamique en présence d'un agent de vulcanisation de type peroxyde.

25 10. Utilisation des compositions selon l'une des revendications 1 à 9 en tant que caoutchouc industriel moulé ou articles extrudés.